

# Radiological abnormalities in electric-arc welders

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**ABSTRACT** Chest radiographs of 661 British electric-arc welders have been examined by three film readers experienced in the radiology of pneumoconiosis. About 7% of the welders showed signs of small rounded opacities of category 0/1 or greater. No definite evidence of large opacities (Progressive Massive Fibrosis) was seen. The prevalence of chest abnormalities other than pneumoconiosis was 7%. A clear association between prevalence of small rounded opacities of category 0/1 or greater and years of exposure to fumes was established, although few signs of severe grades of simple pneumoconiosis were seen.

Siderosis has been recognised as a hazard associated with welding since 1936 when it was first described by Doig and McLaughlin. Considerable differences in the prevalence of radiographic signs of siderosis have been reported by a number of authors since then. Recent surveys have indicated prevalences varying between zero and 80% category 1 or greater in the International Labour Office classification of radiographs (1970) (Peters *et al.*, 1973; Spáčilová and Koval, 1975). None of these surveys has dealt with British workers and all have been based on relatively few men. The study reported here is concerned with the radiographic status of 661 welders working in the United Kingdom.

While many publications refer to siderosis which is, strictly, radiological changes brought about by inhalation of iron dust, electric-arc welders are exposed to many other substances besides iron dust. For this reason, abnormality in this report is considered in terms of small rounded opacities.

The objects of the study were threefold: to estimate the prevalence of small rounded opacities in the films; to establish the prevalence of other types of abnormality; and to determine whether a dose-response type of relationship exists between duration of exposure to welding fumes and prevalence or severity of small rounded opacities.

## Materials and methods

The population studied consisted of 661 electric-arc

welders, all those currently employed, and 12 men who were all on the company's books but had retired from welding. All the 161 men were, or had been, employed in a heavy industrial plant in West Scotland. Their ages ranged from 16 to 73 years with an average of 36.8 years (Fig. 1).

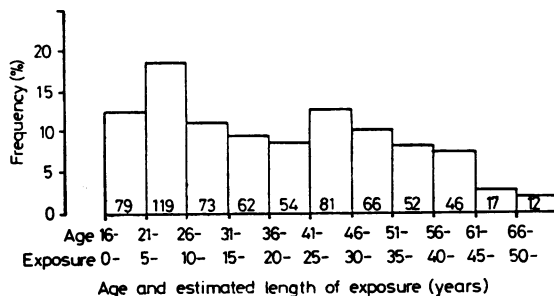


Fig. 1 Distribution of age and estimated years of exposure. (Numbers of men shown in each range.) Total number of men = 661.

A posteroanterior chest radiograph had been obtained at least once for each man. Those considered in this report are the latest and were taken during the period March 1970–October 1973.

## EXPOSURE TO FUMES

There are no records of dust and fume levels which would permit reliable and complete estimation of fume exposure. Instead, length of working life from the age of 16 years has been taken to be an index of exposure, because welders are apprenticed at that age and generally remain in that occupation for life. It would be rare for an older man to become a welder. The men were engaged in many types of electric welding including metal inert gas (M.I.G.)

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and tungsten inert gas (T.I.G.) processes. Fumes would have included manganese, nickel, chrome, zinc and lead as well as iron and oxides of nitrogen.

The early exposure of older men may have been rather different because welding has become a full-time occupation in the last 35 years only. Men over 50 years old may have spent less time per week on welding and may not have had to cope with fumes from the more recently introduced processes. On the other hand, some of the older workers believe that conditions were worse in the past, partly because of the primitive and experimental nature of the electrodes and coatings used then.

About 40% of the men stated that they had, at some time, worked near to where asbestos was being used. The percentage varied from about 35% in young men (20–29 yr) to about 50% in the 50–59 age group. The exposure arose from use of asbestos mats and cloths to retain heat and, to a lesser extent, from welding close to other workers using asbestos. Eleven men had used asbestos-coated welding rods.

#### FILM READING METHODS

Three doctors experienced in reading radiographs read the films. The films, excluding an initial pilot set of 80 films, were sorted into alphabetical order, arranged in batches of 100–150 and sent to each reader in turn. Although only the latest film was of interest, the readers sometimes read earlier films side-by-side with the later film. The classifications of the earlier films have not been taken into account in this study.

Films were classified for profusion of small rounded opacities on the 12-point scale of increasing profusion described by the International Labour Office (1970). Standard films used by readers to assist in classification were those issued by the International Labour Office in 1968. The greatest diameter of the predominant rounded opacities, where observed, was recorded on the scale p, q, r, according to the International Labour Office (1970) convention.

Large opacities were classified, the presence of other chest abnormalities noted, and film technique was assessed. Small irregular opacities were not classified. In consequence it is not possible fully to assess radiological changes arising from exposure to asbestos except for those recorded under 'other abnormalities'.

#### STATISTICAL TREATMENT OF FILM READINGS

In order to simplify the treatment of the data in deriving the dose-response relationship, the three film readings for each man were averaged. Each classification, from 0/– to 3/4, was associated with

an integer ranging from 1 to 12. The three resultant scores were averaged and rounded to form a mean integer score. Borderline cases were rounded up or down randomly. The mean scores were converted back to the usual scale for further analysis. Use of a similar procedure has been described by Liddell and May (1966) and has been justified for certain applications by Jacobsen (1975).

#### Results

No one reader read all the available films; reader X read 658, Y read 659 and Z, 652. Six hundred and forty-nine films were examined by all three readers. Film quality was found to be acceptable in over 94% of the films by every reader.

The distribution of film readings of the profusion of small rounded opacities is shown in Table 1 for each reader and for the average scores. Between 4.4% and 8.2% of the films were said to be in category 0/1 or greater. The prevalence of category 0/1 or greater derived from the average readings was 7.9%.

The readers agreed on the classification of 576 (89%) of the 649 films read by them all. These 576 films were all said to be in category 0/0. The paired agreement on presence or absence of signs of small opacities (taking the boundary to be between categories 0/0 and 0/1) was over 93%. However, exact agreement on category for those films placed in category 0/1 or greater by one or both of each pair of readers varied from 3% to 12%.

Most of the films said to show small rounded opacities were graded for size of opacity (Table 2). All readers said that type q (1.5–3 mm in diameter) opacities occurred most often (63%–85%). The next most predominant size was type p (up to 1.5 mm) and this was again noted by all readers. Only one reader reported opacities between 3 mm and 10 mm in diameter (type r). Paired agreement between readers varied from 60% to 80%.

Large opacities sufficient for classification as category A were reported by one reader for one man. Another reader noted tuberculosis for the same subject.

The prevalence of abnormalities other than small or large opacities due to pneumoconiosis is shown in Table 3. All signs of abnormality recorded are included in Table 2 regardless of the degree of confidence placed in their observation. For instance, nearly all diagnoses of bronchitis were tentative. The readers agreed on the classification of 583 (90%) of the 649 films read in common; most of the agreements occurred for films showing no abnormality.

The most common reportedly abnormalities were tuberculosis, pleural changes and other diseases. Of

Table 1 Profusion of small rounded opacities. Distribution of film readings among the different categories

Reader	Profusion												No. of film readings	Total films classified as 0/1+
	0/-	0/0	0/1	1/0	1/1	1/2	2/1	2/2	2/3	3/2	3/3	3/4		
X		629* (95.6)	15 (2.3)	3 (0.5)	8 (1.2)		1 (0.2)				2 (0.3)		658 (100.0)	29 (4.4)
Y		605 (91.8)	22 (3.3)	10 (1.5)	5 (0.8)	4 (0.6)	7 (1.1)	4 (0.6)	2 (0.3)				659 (100.0)	54 (8.2)
Z		610 (93.6)	14 (2.1)	12 (1.8)	8 (1.2)	1 (0.2)	3 (0.5)	3 (0.5)			1 (0.2)		652 (100.0)	42 (6.4)
Average classification		598 (92.1)	28 (4.3)	10 (1.5)	5 (0.8)	5 (0.8)	1 (0.2)		1 (0.2)	1 (0.2)			649 (100.0)	51 (7.9)

\*Figures in brackets are percentages of total film readings.

Table 2 Distribution of films with category 0/1+ by type of opacity

Reader	Films classified into type of opacities			Total	Films not classified by type	Total films with category 0/1+
	p*	q	r			
X	6 (21.4)†	22 (78.6)		28 (100.0)	1	29
Y	8 (15.1)	45 (84.9)		53 (100.0)	1	54
Z	7 (23.3)	19 (63.3)	4 (13.3)	30 (100.0)	12	42
Pooled	21 (18.9)	86 (77.5)	4 (3.6)	111 (100.0)	14	125

p\* = rounded opacities up to about 1.5 mm diameter; q = rounded opacities exceeding 1.5 and up to 3 mm diameter; r = rounded opacities exceeding 3 mm and up to 10 mm diameter.

†Figures in brackets are percentages of total films classified by type of opacity.

Table 3 Prevalence of other types of chest abnormality

Reader	Abnormalities apart from small rounded opacities							Total	No abnormality	Total (all films)
	TB*	PL	EM	FR	BR	CA	Other			
X	15 (26.8)†	13 (23.2)	3 (5.4)	3 (5.4)	7 (12.5)		15 (26.8)	56 (100.0)	602	658
Y	8 (38.1)	5 (23.8)					8 (38.1)	21 (100.0)	638	659
Z	16 (34.8)	9 (19.6)		2 (4.3)	3 (6.5)	3 (6.5)	13 (28.3)	46 (100.0)	606	652
Pooled	39 (31.7)	27 (22.0)	3 (2.4)	5 (4.1)	10 (8.1)	3 (2.4)	36 (29.3)	123 (100.0)	1846	1969

TB\* = Tuberculosis, active or inactive; PL = Pleural abnormality; EM = Emphysema; FR = Fracture; BR = Bronchitis or bronchiectasis (sometimes includes emphysema); CA = Cancer.

†Figures in brackets are percentages of total films classified as showing abnormality.

those men reported to show pleural abnormalities only one was noted to have pleural calcification by one reader; most of the tuberculosis diagnosed was recorded as inactive.

#### RELATIONSHIP BETWEEN PREVALENCE OF SMALL OPACITIES AND LENGTH OF WORKING LIFE

During his working life a welder receives a dose of irritant fume and dust which may cause a response in his lungs that can be measured by examination of his chest radiograph. In the absence of any long-term measurements of exposure, length of working life must be used as an approximation. In general this is satisfactory since welders are commonly apprenticed to welding when they are 16 years old,

and remain in that occupation for life.

A number of different response variables can be derived. One of the more meaningful and simple is the prevalence of category 0/1 or greater. This variable gives a clear indication of how common the dust-induced abnormality is among the study population, and can be easily related to the duration of exposure.

Table 4 shows the prevalence of category 0/1 or greater by time spent working in welding (age—16 years) for each reader and for the average readings. There is little sign of abnormality until 15 years of exposure have passed. After that time the prevalence of pneumoconiosis rises steadily with age until it is over 30% at retirement.

In order to quantify the relationship between

Table 4 Relationship between estimated years of exposure and prevalence of small round opacities (category 0/1 or greater) for each reader and according to average scores

Reader	Exposure (years)											All exposures
	0-	5-	10-	15-	20-	25-	30-	35-	40-	45-	50-	
X	0.0* (78)	0.0 (119)	0.0 (72)	0.0 (62)	1.9 (54)	6.2 (81)	4.6 (65)	9.6 (52)	15.2 (46)	29.4 (17)	25.0 (12)	4.4 (658)
Y	0.0 (79)	0.0 (119)	0.0 (72)	1.6 (62)	5.6 (54)	8.6 (81)	18.5 (65)	19.2 (52)	28.3 (46)	23.5 (17)	33.3 (12)	8.2 (659)
Z	0.0 (78)	0.8 (119)	0.0 (71)	1.6 (62)	3.8 (53)	10.0 (80)	12.1 (66)	9.8 (51)	18.2 (44)	31.2 (16)	33.3 (12)	6.4 (652)
Average scores	0.0 (77)	0.0 (119)	0.0 (70)	1.6 (62)	5.7 (53)	11.2 (80)	12.3 (65)	21.6 (51)	18.2 (44)	43.7 (16)	33.3 (12)	7.9 (649)

\*Prevalence, and number of men (in brackets).

estimated exposure and prevalence a linear logistic model has been fitted to the average readings. Cox (1970) has cited this function as appropriate for data of this nature, and Jacobsen (1973) has used it in his investigations of the dust/disease relationship in coalminers. The model expresses the prevalence as a function of length of exposure:

$$\log \left[ \frac{p}{1-p} \right] = \alpha + \beta.L$$

where  $p$  is the prevalence of category 0/1 or greater small rounded opacities seen in a group of welders exposed to fume for  $L$  years. The parameters  $\alpha$  and  $\beta$  are estimated from the data. Their values were found to be  $\alpha = -5.372$  and  $\beta = 0.102$  and the fitted line has been drawn with the observed data in Figure 2. The fit of the model to the data is satisfactory; the chance that the value of  $\beta$  observed is truly zero is less than 0.001. Interpolation of the fitted line indicates that 10% of men would have category 0/1 or higher at age 47, and that 40% of the men would be so affected at retirement at 65 years.

The relationship of the severity of the profusion of small opacities to length of exposure has been examined. There appears to be some increase in the numbers of men with more advanced categories with age up to 50 years. In men older than this, however, there are no signs of severe grades of pneumoconiosis.

## Discussion

When the films were being classified, readers sometimes had available earlier films for the same man. Reger *et al.* (1973b) have shown how simultaneous classification of serial films from the same man may influence classifications and estimates of variability. It cannot be assumed therefore that the results reported here represent completely (statistically) unbiased estimates of similarity of appearance between

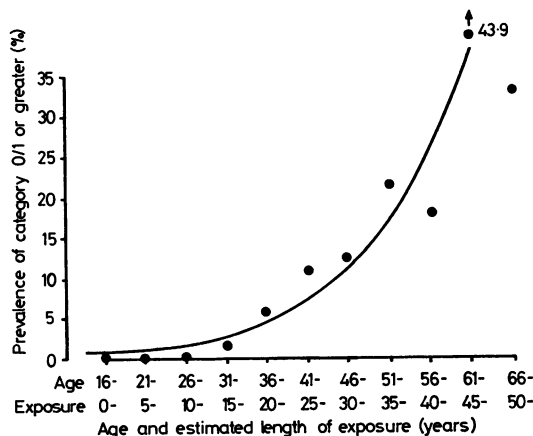


Fig. 2 Relationship between observed and predicted prevalence of small rounded opacities, and age and estimated duration of exposure. Average scores.

the films examined and the international standards.

A further possible source of bias in the classifications recorded arises from the fact that each of the three readers read all of the films in the same order. Temporal variation in standards over the period of film reading could possibly have biased the classifications.

It must be emphasised that the results and estimates made from the fitted equations apply only to welders still employed or retired from the industry. If there is any tendency for those men affected by welding fumes to leave the industry the results presented here will underestimate the true effect of welding as an occupation. This is not thought likely to be the case.

The major disadvantage of the present data is the lack of any direct measure of fume exposure. Welders may smoke and, like other people living in the urban environment, are subject to the effects of air

pollution. Years of work in welding, therefore, not only reflect the degree of exposure to fume, but also measure the extent to which the person has suffered from other non-occupational environmental insults. Consequently it is not possible to distinguish the effects of occupational from non-occupational exposure in this study.

To our knowledge, there is no published information on the prevalence of small rounded opacities in urban-dwelling men not exposed to dust or fume. Some insight into the problem can be gained from study of a group of coalminers exposed to low dust levels, forming part of an investigation by Rae *et al.* (1971). In Table 3 of their report, Rae and colleagues classified miners according to coal dust exposure and age. The results showed a clear relationship between dust exposure and prevalence of category 0/1 or higher small rounded opacities. Despite taking dust exposure into account, an age effect was still seen. Jacobsen (1976) discusses some alternative explanations for this apparent effect. In the group of men with the lowest dust exposures, the age effect amounted to a change in prevalence from zero to 15% over about 30 years until age 55-9. Although substantial, this is still less than the change in prevalence seen in the present study over the same age range. The implication is that exposure to welding fume is associated with radiological changes over and above those possibly arising from non-occupational exposure or other effects associated with ageing.

Sadoul (1972) states that signs of pneumoconiosis in arc-welders (siderosis) do not usually become apparent until after about 10-15 years' exposure. After this, he says, the prevalence rises with length of exposure but the severity of the disease rarely passes category 2/2 and there is little evidence of large opacities. The opacities are noted to be predominantly type q, sometimes type p and rarely size r. In terms of small rounded opacities this is exactly what was found in the present study. The assertion that opacities were both reticular and nodular cannot be verified because the films were not read for small irregular opacities. If the films had been read for such opacities, the incidence of lung abnormalities might have been higher than that reported here.

The striking agreement between the results of the present survey and the description given by Sadoul is in contrast to the contradictory findings given by other researchers. Kleinfeld *et al.* (1969) noted that eight of 25 welders had reticulonodular shadowings on the radiographs consistent with siderosis. This prevalence rate of 32% is in contrast to the 3% reported by Fogh and colleagues (1969) for 156 arc-welders. Peters *et al.* (1973) found no signs of siderosis in their study of 61 arc-welders. This differs remarkably from the 81% prevalence of category 1 or more reported

by Spáčilová and Koval in 1975.

It is possible to speculate on the causes of these differences but lack of information precludes their being explored to any extent. Differences in dust and fume concentrations and varying patterns and duration of exposure may have resulted in differing doses being received. On the other hand, differing film reading standards may have given rise to some of the variation between observers. Reger *et al.* (1973a) have shown how two sets of readers using similar standard films can differ. The published information on exposure and on standards is scanty and does not help to resolve differences between studies.

There are relatively few men with severe grades of simple pneumoconiosis in the present study. This, as suggested by Doig and McLaughlin (1948) and seen also by Garnuszewski and Dobrzynski (1967), may be attributable to the regression of signs of siderosis when exposure ceases. On the other hand, the exposure of the older men may not have been as great as their age suggests, because welding as a continuous occupation has become common only in the last 35 years. There is also the possibility that the natural history of siderosis is such that severe grades seldom arise.

No readings of small irregular opacities were undertaken as it was not the purpose of this investigation to study the radiological effects of asbestos exposure in welders. Despite this, we would expect that the experienced readers who participated in this study would have drawn attention to the presence of irregular opacities if they had been observed frequently. In fact, one reader did note irregular opacities in one man. Apart from this, and the one man with pleural calcification, there was little evidence of asbestosis in this study. In an independent screening of the films by one of the authors (DSR) there was no indication of asbestosis.

The film reading was performed by Drs S. Rae, D. D. Walker and P. Prentice.

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